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UNITED STATES PATENT APPLICATION

FOR

TAPE BACKUP SYSTEM

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1 1. FIELD OF THE INVENTION

2 This present invention relates to data archival systems for use with computer systems and,
3 more specifically, to a tape backup system compatible to be coupled with a hard disk controller on,
4 for example, an IBM PC/AT or compatible.

6 2. BACKGROUND OF THE INVENTION

7 Virtually anyone who uses a computer system, and especially, a personal computer system,
8 has considered the possibility of some hardware failure making data stored on that system
9 inaccessible. The unfortunate among us have not only considered the possibility, but have had the
10 possibility become a reality. Due to this possibility, it is today commonplace to employ some
11 backup (or archival) system to periodically copy data stored in the computer system in order that
12 the data may be restored at a later time in the event of such a hardware failure. In the personal
13 computer world, most commonly, the backup system either employs so-called "floppy disks" onto
14 which data is transferred, through the computers floppy disk drives, for storage or a tape drive
15 which is coupled to the computer and which allows data to be communicated between the computer
16 and tape drive for recording onto a tape medium (e.g., magnetic or optical tape).

17 In personal computers, such as the IBM PC and compatible family, known tape drives are
18 coupled with the computer through a floppy disk interface. This design is employed largely to
19 save the cost of requiring a separate controller for the tape drive and to avoid occupying one of the
20 computer's slots with a separate tape controller. However utilizing the floppy controller as an
21 interface presents certain problems in the operation and design of a backup system. For example,
22 in the typical IBM PC or compatible, a floppy drive controller is capable of supporting up to two
23 separate drives. Using one of the slots on the floppy drive controller to interface with a tape drive
24 may be undesirable. Further, use of the floppy drive controller allows for a relatively slow
25 interface data rate, e.g., 500 kilobits per second (Kb/s). Present day disk controllers may provide
26 for relatively faster interface data rates, e.g., 5 or more megabits per second (Mb/s). Therefore, it

1 is desired to provide for coupling of a tape drive to a controller having a interface data rate more
2 compatible with present day disk controllers.

3 Therefore, as one object of the present invention it is desired to provide a tape drive design
4 which allows interfacing a tape drive to a computer system without need to interface through the
5 floppy controller.

6 It is, of course, possible to provide for interfacing of a tape drive through a separate and
7 relatively faster interface. However, in computer systems such as may utilize the preferred
8 embodiment of the present invention, a separate interface requires use of one of a limited number
9 of "card slots" on the motherboard of the computer system. Users of such computer systems
10 generally prefer to avoid use of card slots whenever possible so that the card slots may be saved
11 for other uses.

12 Therefore, as a second object of the present invention, it is desired to provide an interface
13 for a tape backup system which does not require use of a separate card slot for interfacing with the
14 host computer.

15 Recently, an interface has been developed known as the Intelligent Device Electronics
16 (IDE) interface. The IDE interface typically allows for interfacing of at least two hard disk drives,
17 each having an embedded controller. In typical operation, one disk drive may be addressed by the
18 host computer through standard operating system routines in order to access data on that drive.
19 During the time when the disk drive is executing the command to access data, the drive sets a bit
20 indicating the interface is busy, preventing the host computer from issuing additional commands
21 over the interface (e.g., a command to write data to the second device). Therefore, the IDE
22 interface, utilizing standard operating system commands, is relatively incompatible with attempts to
23 couple a tape drive to the device for purposes of "backing up" a disk drive coupled with the
24 interface.

1 It is therefore, an object of the present invention to provide apparatus and methods for
2 interfacing a tape drive with an IDE interface and to allow simultaneous operation of a disk drive
3 and the tape drive coupled with the interface.

4 Finally, embedded controller circuits on present day disk drives designed for coupling with
5 the IDE interface typically comprise standard, off-the-shelf, disk controller circuits, such as the
6 Cirrus Logic CL-SH-260 disk controller circuit. It is desired to develop a tape drive utilizing
7 standard, off-the-shelf, disk controller circuits. However, certain incompatibilities exist between
8 outputs provided by such circuits and formats compatible for writing to industry standard tapes.

9 Therefore, as another object of the present invention, it is desired to provide circuitry for
10 adapting outputs of standard, off-the-shelf, disk controller circuits to provide data compatible for
11 writing industry standard tape formats.
12

1
2 SUMMARY OF THE DISCLOSURE

3 A data archival system is disclosed which is especially useful in computer systems, for
4 example, in computer systems known as IBM PC's and compatibles therewith. The data archival
5 system preferably comprises a tape backup device coupled with an Intelligent Device Electronics
6 (IDE) interface such as may be available on an IBM PC/AT or compatible.

7 In particular, the present invention teaches a computer system having an interface for
8 interfacing with at least a first storage device and a second storage device. Preferably the first
9 storage device comprises a disk drive or similar random access storage apparatus. The second
10 storage device preferably comprises a tape drive or similar data archival device. The first storage
11 device comprises a first indicator having a first state for indicating the device is executing a
12 command and a second state for indicating the device is not executing a command. The second
13 storage device comprises a second indicator having a first state for indicating the second device is
14 receiving information over the interface and a second state for indicating the second device is not
15 receiving information over the interface.

16 Thus, the second device may receive information over the interface and during a period of
17 time associated with receiving the information the second indicator may be in its first state thereby
18 indicating the second device is receiving data. Upon completion of receiving the information, the
19 second indicator may change states to indicate the second device is no longer receiving data. The
20 second device may subsequently process the received information, such as by preferably accessing
21 a storage medium such as tape and either reading or writing information thereto. At the same time,
22 a command may be communicated to the first storage device over the interface; responsive to
23 receiving the first command, the first storage device may set the first indicator means to a first state
24 to indicate it is processing the command. For example, the command may instruct the device to
25 read data from a disk storage media. Upon completion of the command, the first indicator means
26 is returned to a state indicating the first storage device is not executing a command.

1 It is taught that the second device may continue executing a command after having
2 completed receipt of information through the interface and after having set the second indicator to
3 indicate completion of receipt of such information. For example, the second device may have
4 received a command to write data to tape and, further, the second device may have received such
5 data, for example, into a buffer memory. Subsequent to having received such a command and
6 data, the second device may set its indicator to indicate it has completed receipt of the information
7 and a processor may then direct a command to the first device to read data from a disk. The second
8 device may then continue the process of writing data to tape simultaneously with the first device
9 reading information from ^{disk}~~tape~~. Importantly, this simultaneously operation is accomplished while
10 having both the first and second device coupled with a single interface.

11 The present invention further discloses use of a data archival application process for
12 managing access to an interface having coupled thereto a disk drive and a tape drive wherein the
13 application process initially replaces interrupt vectors pointing to standard ROM BIOS disk service
14 routines with vectors pointing to routines in the data archival application. The application is then
15 able to manage access to the disk service routines. Specifically, during operation the data archival
16 process may call an operating system routine to, for example, read data from the disk for archival
17 onto the tape. The operating system routine attempts to access the disk service routine through the
18 appropriate intercept vector. However, as taught by the present invention, the application has
19 replaced the address in the intercept vector with an address a routine in the archival application.
20 Therefore, the data archival application intercepts the call to the disk service routine. The data
21 archival application then switches control of the interface from the tape drive to the disk drive and
22 then calls the ROM BIOS disk service routines.

23 In this manner, the data archival application may control simultaneous operation of the disk
24 and tape drive while utilizing the ROM BIOS disk service routines to ensure compatibility.

1 In addition, a format adapter circuit is disclosed which advantageously allows use of
2 industry standard disk controller circuits in a tape drive and provides for adapting output signals of
3 such disk controller circuits to a format compatible with industry standard tape formats.

4 These and other aspects of the present invention will be better described with reference to
5 the Detailed Description of the Preferred Embodiment and the accompanying Figures.

1
2 BRIEF DESCRIPTION OF THE DRAWINGS

3 Figure 1 is a block diagram illustrating a computer system as may be utilized by the present
4 invention.

5
6 Figure 2 is a block diagram illustrating coupling of a host computer through an IDE
7 (Intelligent Drive Electronics) interface to a tape drive and a disk drive as is taught by the present
8 invention.

9
10 Figure 3 is a block diagram illustrating components of a tape drive of the present invention.

11
12 Figure 4 is a block diagram further illustrating certain components of a tape drive of the
13 present invention including a controller circuit, an IDE interface, a microprocessor, a RAM and a
14 write/read interface.

15
16 Figure 5 is a diagram illustrating contents of a task file as may be implemented by the
17 present invention.

18
19 Figure 6 is a diagram illustrating contents of a write control store as may be utilized by the
20 present invention.

21
22 Figure 7(a) is an illustration of an encoder circuit and corresponding timing information as
23 may be utilized by the present invention.

24
25 Figure 7(b) is an illustration of an decoder circuit and corresponding timing information as
26 may be utilized by the present invention.

1
2 Figure 8 is a flow diagram illustrating an overall process for backing up a hard disk drive
3 as may be utilized by the present invention.

4
5 Figure 9 is a flow diagram illustrating a backup loop of the backup process as may be
6 utilized by the present invention.

7
8 Figure 10 is a flow diagram illustrating a method for reading information from disk as may
9 be utilized by the present invention.

10
11 Figure 11 is a flow diagram illustrating a data restore process as may be utilized by the
12 present invention.

13
14 Figure 12 is a flow diagram illustrating a restore data loop as may be utilized in the data
15 restore process of the present invention.

16
17 Figure 13 is a flow diagram illustrating a method of writing information to a disk as may be
18 utilized by the present invention.

19
20 Figure 14 is a diagram illustrating DOS address space as may be configured by the present
21 invention.

22
23 Figure 15 is a flow diagram illustrating a prior art method of executing commands by a disk
24 drive.
25

- 1 Figure 16 is a flow diagram illustrating a method of the present invention for executing
- 2 commands by a tape drive.

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

2 A tape backup system is described. In the following description, numerous specific details
3 are set forth such as specific circuits, etc., in order to provide a thorough understanding of the
4 present invention. It will be obvious, however, to one skilled in the art that the present invention
5 may be practiced without these specific details. In other instances, well-known circuits, structures
6 and techniques have not been shown in detail in order not to unnecessarily obscure the present
7 invention.

8
9 OVERVIEW

10 The computer system of the preferred embodiment

11 The overall computer system of preferred embodiment is described with reference to Figure
12 1. The preferred embodiment of the present invention is implemented on one of members of the
13 IBM Personal Computer family or computer systems compatible with members of this family. In
14 particular, the computer system of the present invention is implemented on a IBM PC/AT or
15 compatible implementing the Intelligent Drive Electronics (IDE) interface 107 (also known as the
16 "AT-Drive" interface or the ATA (AT attachment) interface. The IDE interface will be discussed in
17 greater detail below. It will, of course, be obvious to one of ordinary skill in the art that any
18 number of other computer systems may employ the teachings of the present invention.

19 In any event, a computer system as may be utilized by the preferred embodiment generally
20 comprises a bus or other communication means 101 for communicating information, a processing
21 means 102 coupled with the bus 101 for processing information, a random access memory (RAM)
22 or other dynamic storage device 104 (commonly referred to as a main memory) coupled with said
23 bus 101 for storing information and instructions for said processor 102, a read only memory
24 (ROM) or other static storage device 106 coupled with said bus 101 for storing static information
25 and instructions for said processor 102, an interface¹¹¹ for allowing coupling of data storage devices,
26 such as hard disk 107 (in addition, as will be seen, a data archival device such as a tape drive may

1 be coupled with the interface), with the bus 100 for storing information and instructions, a display
2 device 122, such as a cathode ray tube, liquid crystal display, etc, coupled to the bus 101 for
3 displaying information to the computer user, an alphanumeric input device 125 including
4 alphanumeric and other keys coupled to said bus 101 for communicating information and
5 command selections to said processor 102, and a cursor control device 127, such as a mouse, track
6 ball, cursor control keys, etc, coupled to said bus 101 for communicating information and
7 command selections to said processor 102 and for controlling cursor movement. Finally, it is
8 useful if the system includes a hardcopy device 129, such as a printer, for providing permanent
9 copies of information. The hardcopy device 129 is coupled with the processor 102, main memory
10 104, static memory 106 and mass storage device 107 through bus 101.

11 The processor 102 of the preferred embodiment is one of the 80x86 microprocessor family
12 manufactured by Intel Corporation of Santa Clara, California. In the preferred embodiment, the
13 system is operated using a standard IBM PC-compatible operating system such as MS-DOS
14 available from Microsoft Corporation of Beaverton, Oregon.

15 It will be apparent, from an understanding of the present invention from the below
16 description, that several of the above-mentioned components of the computer system of the
17 preferred embodiment are not essential to operation of a computer system employing aspects of the
18 present invention. For example, as will be described in more detail below, the display 122,
19 keyboard 125, cursor control device 127, and hard copy device 129 may not be present in certain
20 implementations.

21 22 The IDE Interface

23 The IDE interface has evolved from earlier hard disk interfaces in which a hard disk adapter
24 card, including a controller, was installed in a "slot" of a computer system. Such hard disk adapter
25 cards are typically capable of supporting up to two hard disk drives, although only one drive may
26 be written to or read from at a time. The two drives interface to the card through an interface

1 known as the ST506 interface. More recently developed hard disk drives comprise an embedded
2 controller and processor removing the requirement for the adapter card to include its own
3 controller. The interface allowing for use of embedded controllers in a hard disk is known as the
4 IDE or Intelligent Device Electronics interface. The programming model and command codes for
5 the IDE interface are the same as for the ST506 interface; however, as controllers are embedded in
6 the drives themselves, the IDE interface must allow for two controllers to be coupled with the
7 interface and must provide for proper management of information transferred. To manage access
8 to the drives, the IDE interface depends on a status bit (the BUSY bit) in a set of registers (the
9 "task file") associated with each drive. The task file 500 and the BUSY bit 521 of the preferred
10 embodiment are described in greater detail below with reference to Figure 5.

11 Figure 2 illustrates in somewhat greater detail the coupling of a data archival device 108 and a
12 hard disk storage device 107 with an IDE interface 111 of a host computer 201. In particular, the
13 data archival device 108 and hard disk storage device 107 are both coupled to communicate data
14 with the host computer 201 over data lines 202. The preferred embodiment provides 16 lines for
15 communication of data between the host computer 201 and devices 107 and 108. In addition,
16 devices 107 and 108 are coupled to receive 3 bits of address information on lines 203 and to
17 receive control information on line 204 through interface 111. The control information comprises
18 read/write strobes, chip select control information and ready signals.

19 Finally, the devices 107 and 108 are coupled to provide interrupts to the host computer
20 through interface 111 on line 205.

21 The circuitry of the data archival device ¹⁰⁸~~107~~ of the preferred embodiment is described in
22 greater detail with reference to Figure 3. Figure 3 illustrates the device ¹⁰⁸~~107~~ comprises a connector
23 301 for coupling with the IDE interface 111 of the host computer 201. The connector 301 is
24 preferably a 40-pin connector and comprises ¹⁰⁸16 data pins for communicating data information
25 between a controller circuit 302 of the device ¹⁰⁸~~107~~ and the interface 111 of the host computer 201; 3
26 address pins for receiving address information from the host computer 201 for communication to

1 the circuit 302; a control pin for receiving control information from the computer 201 for
2 communication to the circuit 302; an interrupt pin for signalling interrupts generated by the circuit
3 302 to the computer 201; and a ready signal line for communicating ready status to the computer
4 201.

5 The controller circuit 302 is responsible for communicating information with the host
6 computer over connector 301; for managing access to RAM buffer 303; and for formatting data to
7 be written by the device. In the preferred embodiment, part number CL-SH260 Hard Disk
8 Controller available from Cirrus Logic, Inc. of Milpitas, California is utilized. However, in
9 alternative embodiments it is recognized that alternative circuitry may be utilized. For example,
10 functions of the CL-SH260 may be implemented in discrete circuitry, in a gate array or in a
11 programmed logic array. Further, alternative commercially available circuits may be employed
12 which provide similar or compatible circuitry. For example, part number AIC-6060 hard disk
13 controller available from Adaptec may be substituted as a compatible part.

14 The controller circuit 302 is illustrated in greater detail with reference to Figure 4. As
15 previously stated, the controller circuit 302 provides the functions of interfacing with the host
16 computer through host interface section 402; of providing for buffer management of RAM buffer
17 memory 303 through buffer manager section 404; and of providing for formatting data through
18 formatter section 403. The particular workings of each of these sections will be well understood
19 by one of ordinary skill in the art, especially with an understanding of the CL-SH260 controller
20 circuit as utilized by the present invention. Further information on the CL-SH260 controller is
21 available from Cirrus Logic, Inc. as CL-SH-260 Integrated PC XT/AT Disk Controller Data Sheet
22 and Application Notes AN-SH1 & AN-SH5. However, it is worthwhile to discuss here that the
23 controller 302 provides registers for the task file 500 as part of host interface 500. The task file
24 register 500 will be described in greater detail below with reference to Figure 5. Additionally,
25 formatter section 403 ^{Provides a writeable} provides write control store circuitry 409 for storage of control information.
26 Write control store 409 will be discussed in greater detail below with reference to Figure 6.

1 The controller circuit 302 is coupled to communicate control, data and interrupt information
2 with processor 304 and gate array 307. Processor 304 and gate array 307 are provided to control
3 the drive electro-mechanics such as circuitry for controlling tape movement. In the preferred
4 embodiment, the processor 304 is an Intel 8052 microprocessor. Again, it will be apparent to one
5 of ordinary skill in the art that alternative embodiment may employ alternative processing means to
6 provide for control of the controller circuit 302.

7 In addition to providing for control of the drive electro-mechanics, processor 304 is
8 programmed, via 32K ROM 305, to provide certain control over controller circuit 302. Of
9 particular interest to the present invention, and as will be discussed in greater detail below,
10 processor 304 is programmed to set the BUSY bit whenever information (i.e., a command or data)
11 is being received over the interface and to clear the BUSY bit after the information has been
12 received.

13 The formatter section 403 of controller 302 is further coupled to provide output information
14 to encoder 311 and to receive input information from decoder 312. In the preferred embodiment,
15 controller 302 is designed to provide output information to encoder 311 and to receive input
16 information from decoder 312 in a format commonly referred to as modified FM or MFM.
17 Encoder 311 is provided to convert the MFM information to non-return to zero (NRZ) format in a
18 well known fashion. Decoder 312 is provided to convert NRZ information back to MFM
19 information for presentation to the controller 302, again in a well known fashion. Encoder 311
20 and decoder 312 are implemented as programmed logic arrays in the system of the preferred
21 embodiment. Although it is known in prior art hard disk drive systems to provide circuitry for
22 encoding MFM signals and decoding NRZ signals, certain advantages of the encoder 311 and
23 decoder 312 allowing for use of the circuitry of the present invention with a data archival system
24 and, specifically, with a tape drive format as utilized by the preferred embodiment. These
25 advantages will be described in greater detail below with reference to Figures 6, 7(a) and 7(b).

26 The Task File

1 As can be seen with reference to Figure 5, the task file 500 of the preferred embodiment of
2 the present invention comprises ten separate eight-bit registers which may be referred to as (1) the
3 status register 501; (2) the alternate status register 502; (3) the drive select register 503; (4) the
4 error code register 504; (5) the segment number (low) register 505; (6) the segment number (high)
5 register 506; (7) the segment count register 507; (8) the mode register 508; (9) the data register
6 509; and (10) the digital input register 510.

7 The Status Register 501

8 The status register comprises eight indicator bits. Of particular interest to the present
9 invention is the BUSY bit 521 (bit 7 counting from bit 0 at the right). In a typical disk drive
10 operation in the prior art, at the beginning of a command sequence, the BUSY bit 521 is set under
11 the control of a local processor. The BUSY bit 521 remains set until completion of an operation.
12 During the time period when the BUSY bit 521 is set, the host computer is not allowed access to
13 the remaining registers in the task file 500. Further, the host computer may not access any other
14 device coupled with the IDE interface during the time period when one controller coupled with the
15 bus has its BUSY bit 521 set. In essence, the BUSY bit 521 is used as a collision avoidance
16 mechanism and it is assumed in prior art systems utilizing the IDE interface that it is not desirable,
17 and in fact, it is not allowed, to access two devices coupled with the IDE interface simultaneously.
18 After the BUSY bit 521 is cleared, the controlled^{er} is not allowed to change the contents of the
19 remaining registers of the task file 500. Thus, it is understood that, in prior art systems, the use of
20 the BUSY bit 521 as a contention avoidance mechanism prevents access to one device coupled
21 with an IDE interface when a second device, also coupled with the same IDE interface is busy
22 executing a command. In essence, the interface simulates a situation in which a single controller is
23 available to control access to both devices.

24 It should be noted that the IDE interface allows for one special case, the SEEK command,
25 in which the controller clears the BUSY bit 521 after beginning execution of the command and
26 prior to its completion. Therefore, a second drive coupled with the IDE interface may be accessed

1 while the SEEK command is executing. Implementation of this special case in the IDE interface
2 requires use of a special status bit (SEEK Complete) in the task file of the disk drive.

3 As will be seen, the present ^{invention} provides capability for simultaneous reading and writing access
4 to a data archival device and a hard disk, both attached to a single IDE interface of a host computer.

5 The status register is also used as a command register and is written with the command to
6 be executed.

7 The Drive Select Register 503

8 The drive select register 503 is written by the host computer to select either one of the two
9 drives coupled with the IDE interface before programming of the task file registers and issuing
10 commands. In the preferred embodiment, a hard disk drive may be attached as drive 0 (also
11 referred to as the "master") and a tape drive may be attached as drive 1 (also referred to as the
12 "slave"). In certain embodiments, such as a system with a secondary IDE channel, the tape drive
13 could be coupled as drive 0. Use of the BUSY bit will be discussed in greater detail below.

14 In the preferred embodiment, a drive select bit 522 (bit 4 counting from bit 0 being the far
15 right hand bit) is set or cleared to select the desired drive. The remaining bits (bits 0-3 and 5-7) are
16 not used in current implementations.

17 The Alternate Status Register

18 The alternate status register 502 is identical to the status register 501; however reading the
19 alternate status register does not acknowledge and clear interrupt requests which are acknowledged
20 and cleared by reading the status register 501. This register is useful where it is desired to be able
21 to inquire into the device status without losing a pending interrupt.

22 The Error Code Register

23 The error code register 504 is a two field register indicating error information: an error report
24 pending status bit and a 7-bit error code.

25 The Data Register

1 The data register 509 is utilized to allow direct interface with the tape controller's buffer
2 management logic to allow reads or writes with the drives buffer RAM memory.

3 The Segment Count Register

4 The segment count register 507 is loaded with a segment count prior to issuing a read or a
5 write command. If a count of zero is loaded, it is interpreted as an indefinite count and the
6 command will continue until terminated by another command. During the transfer of data, the
7 segment count is updated by the tape drive after each segment is transferred, unless an indefinite
8 count is specified.

9 The Segment Address Registers

10 The segment address registers 505 and 506 are loaded with a beginning segment address
11 prior to reading or writing to the tape. The segment address is a 16-bit value with the low order
12 eight bits stored in register 505 and the high order eight bits stored in register 506. During multiple
13 segment read and write operations, the segment address is incremented as each transfer is
14 completed.

15 The Mode Register

16 The mode register 508 comprises a set of bits to control and report operational modes of the
17 tape drive of the preferred embodiment including a format code, length of tape code, tape cartridge
18 present code, tape cartridge write protected code, interrupt mode select, and a data packing method
19 code.

20 SIMULTANEOUS OPERATION OF THE TAPE AND DISK DRIVES

21 Prior art methods of operating data archival devices in, for example, an IBM PC or
22 compatible, provide for coupling the tape drive through a interface separate from the interface for
23 the hard disk. For example, it is common to couple a tape drive to a floppy disk interface. In this
24 way, one interface is available for allowing access to the disk drive while a separate interface is
25 available for allowing access to the tape drive. In this arrangement, the respective interfaces may
26 operate to allow simultaneous operation of the tape and disk drives. However, in certain computer

1 systems it is desirable for a number of reasons to allow for coupling of both a tape and disk drive
2 through a single interface.

3 Therefore, as one aspect of the present invention it is disclosed to allow coupling of both a
4 tape drive and a disk drive to a single interface while providing for simultaneous operation of both
5 the tape and disk drive.

6 The BUSY Bit

7 Known devices (e.g., disk devices) which interface with the IDE interface operate by setting
8 their BUSY bit in their status register when the device is executing a command. A well-known
9 processing utilized by disk drives which interface with the IDE interface is illustrated with
10 reference to Figure 15. First, the host processor sets the drive select bit 522 to select the disk
11 (e.g., in a typical configuration, the host processor sets the drive select bit to 0), block 1522. The
12 host proceeds to program the task file registers of the disk drive to execute the command, block
13 1502. After the task file registers are programmed by the host, an on-board processor on the drive
14 sets the BUSY bit 521 and begins executing the command. Execution of the command may
15 include communicating (e.g., reading or writing) information over the interface. For example, data
16 to be written to the disk may be communicated by the host processor over the interface to the disk
17 drive. The disk drive may initially accept the data into a buffer memory and then retrieve the data
18 from the buffer memory for writing to disk. Typically, the buffer memory is a higher speed device
19 than the disk itself and, therefore, the host computer may complete transmission of the information
20 before the drive completes execution of the command to write the data to disk. In any event,
21 eventually the disk completes execution of the command, block 1505. Upon completion of the
22 command, the on-board processor clears the BUSY bit, block 1506.

23 During the period the BUSY bit was set (i.e., from block 1503 through block 1506), the host
24 processor is prevented from accessing registers 503-509 of the task file registers on both the disk
a 25 drive and tape drive. As a result, during the period in time when the ^{disk}~~tape~~ drive is executing the

1 command, even after it may have received all necessary information over the interface, the host
2 computer is prevent from accessing the tape drive.

3 Figure 16 illustrates a method of the present invention for processing commands to the tape
4 drive. Similar to the discussion in connection with Figure 15, the host processor initially sets the
5 drive select bit to select the tape drive, block 1601, and the host processor programs the tape drives
6 task file register, block 1602. The tape drives on-board processor then sets the BUSY bit 1603
7 and begins executing the command. For example, the command may be a request to write
8 information to tape, in which case, information is communicated by the host processor, over the
9 interface, to the tape drive, block 1604. After completion of communicating information over the
10 interface, the tape drives on-board processor clears the BUSY bit, block 1605. In the exemplary
11 case of a request to write information to tape, the tape drive may accept information to be written
12 over the interface and temporarily store the information in a relatively high speed buffer memory
13 prior to the information being written to tape. Therefore, the tape drive may not have completed
14 processing of the command prior to clearing the BUSY bit. In any event, at some point in time the
15 tape drive completes execution of the command, block 1606; however, as has been explained, the
16 BUSY bit has been cleared prior to completion of execution of the command. In this way, the host
17 may begin communications with the disk drive while the tape drive completes execution of the
18 command "off-line".

19 The process of backing up and restoring information in the system of the preferred
20 embodiment will be explained in greater detail with reference to Figures 8-14.

21 The Backup Process

22 Figure 8 is an overall flow diagram of a backup (or data archival) process as may be utilized
23 by the present invention. In the preferred embodiment, an application program is provided to
24 manage the backup process. The application program is initialized in any of a number of
25 well-known manners, block 801. For example, a user may input a command into the host
26 computer to initialize or start-up the application process.

1 When the application program initializes it determines and stores the addresses of interrupt
2 vectors for the system hard disk interrupt (referred to as INT 14 in the MS-DOS operating system)
3 and the ROM BIOS hard disk service routine (referred to as INT 13 in the MS-DOS operating
4 system). The application program then installs the address of certain of its own routines in place of
5 the addresses of the interrupt vectors; effectively the application program takes control of the disk
6 service routines, block 802. This may be better understood with reference Figure 14.

7 Figure 14 illustrates certain portions of the address space in an MS-DOS system. The
8 address space includes certain interrupt vectors 1401 including a hard disk interrupt vector
9 (hardware interrupt vector 1402) and a ROM BIOS hard disk service vector (INT 13H vector
10 1403). During typical operations, vector 1402 is an address pointer to the ROM BIOS disk
11 interrupt handler 1423 in the ROM BIOS code 1421 and vector 1403 is a pointer to ROM BIOS
12 INT 13 disk services handler 1422, again in the ROM BIOS code. However, as mentioned above,
13 when the tape application program initializes, interrupt vector 1402 is changed to point to an
14 interrupt handler routine 1413 in the tape application program 1411 and interrupt vector 1403 is
15 changed to point to a "gatekeeper" routine 1412 in the application program 1413.

16 As will be explained in greater detail below, these routines allow the application to have its
17 own driver routines for interfacing with the tape drive and to use the ROM BIOS routines for
18 accessing the disk.

19 The "gatekeeper" routine 1412 ensures that when the operating system (MS-DOS) is
20 accessing the disk, all hardware interrupts are directed to the ROM BIOS's routines for servicing
21 and when the disk is not being accessed, the IDE bus is available for tape drive commands and
22 interrupts.

23 The IDE interrupt gatekeeper and tape drive interrupt function 1413 allows the application
24 to redirect the hardware interrupt vector 1402 to point to the disk service routine when disk drive
25 operations are being performed and to use the applications own interrupt routines when the tape
26 operations are being performed.

1 Referring back to Figure 8, the application program then issues a command to the tape drive
2 to write data to tape (i.e., to backup data) by programming its task file registers, block 803. The
3 application then directs archiving of data from the disk drive to the tape drive by reading data from
4 the disk, blocking the data into 32K blocks, and transferring the data to tape. These functions will
5 be explained in greater detail with reference to Figures 9 and 10.

6 Upon completion of the archival process, the application releases control of the disk service
7 routines by writing the stored addresses for vectors handlers 1422 and 1423 back to vectors 1402
8 and 1403, respectively, block 805. The application then terminates, block 806.

9 Referring now to Figure 9, the processing of backing up data from the disk is essentially a
10 loop in which, first, data is read from the disk, block 901; assuming there is more data to read,
11 block 902, the data is blocked into 32K blocks and transferred to the tape drive, block 904. The
12 process of reading data from the disk is explained in greater detail with reference to Figure 10.
13 This process essentially entails the "gatekeeper" process referred to earlier. Initially, the
14 application program uses operating system calls, in the conventional manner, to request data be
15 read from the disk. The operating system calls attempt to call the disk service routine (INT 13) at
16 the address given by vector 1403. As discussed earlier, the application program had previously
17 replaced the address of INT 13 with the address of gatekeeper function 1413. Therefore, the call
18 to the disk service routine is intercepted by the application program, block 1003.

19 The application program then switches access to the IDE bus from the tape drive to the disk
20 drive (the state of the drive select bit in the drive select register of both the tape and disk drive is
21 inverted, e.g., changed from a 1 to a 0). The tape drive is then disabled from accepting further
22 data transmitted on the bus by clearing the data request status bit 523. In this way, the tape drive is
23 controlled to prevent it from mistakenly accepting data transferred on the interface from the disk
24 drive to the host computer.

25 As previously noted, the application program has stored the address of the ROM BIOS INT
26 13 disk services routine. At this point, having disabled the tape from receiving further data and

1 having set the disk select bit 521 to allow the disk drives task file registers to be programmed, the
2 application program calls the ROM BIOS INT 13 disk services routine to initiate transfer of data
3 from the disk to the host. The ROM BIOS INT 13 routine programs the disks task file registers
4 and the disk begins execution of the command. As discussed previously with reference to Figure
5 15, the disk will set its BUSY bit prevent other accesses to the bus during the time it is executing
6 the command. Upon completion of execution of the command, the disk clears the BUSY bit and
7 the ROM BIOS INT 13 routine returns control to the operating system routine. The operating
8 system routine then returns control to the application process, block 1006.

9 The application program then proceeds to switch communications back to the tape drive by
10 switching the state of the disk select bit (e.g., from a 0 to a 1), block 1007. The tape drives DMA
11 transfer is then again enabled, block 1008, and the application process continues to transfer data to
12 the tape.

13 The Restore Process

14 Figures 11-13 illustrate the process of the preferred embodiment for restoring data from the
15 tape to disk. The restore process is similar to the backup process and begins by initializing the
16 application program, block 1101 and by the application process taking control of the disk services
17 routine, block 1102. The application program then programs the tape drives task file registers to
18 read data from tape, block 1103 and the tape drive begins reading data from the tape and
19 transferring the data to its buffer memory 303 under control of controller 302. The tape drive then
20 transfers the data across interface 301 to the host computer and the application program transfers
21 the data to disk, block 1104 and continues this process until all requested data has been restored
22 (see Figure 12). Upon completion of the restore process, the application process releases control
23 of the disk services processes, block 1105, and terminates, block 1106.

24 The process of transferring data from tape to disk of block 1104 is illustrated in greater detail
25 with reference to Figure 12 which illustrates that initially data is read from tape 1201. In the
26 preferred embodiment, data is read from tape using the method and mechanisms described above.

1 That is, first a command is issued by the host processor to the tape drive. The tape drive then
2 proceeds to read data from tape and to store the data in its internal buffer.. This process may
3 continue without requiring access to the IDE interface (i.e., the tape drive is "offline"). As data is
4 placed in the buffer it may be transferred to the host computer main memory 104 using a DMA
5 transfer facility, block 1203. During the period of time that data is actually being transferred, the
6 tape drive indicates to the host computer that the IDE interface is unavailable for other uses by
7 setting its BUSY bit. After the data is transferred from the data buffer 303 of the tape drive to the
8 main memory 104 of the host computer, the tape drive clears the BUSY bit allowing the tape
9 application software to again control access to the bus.

10 The tape application software then begins the process of writing the data from the main
11 memory 104 to disk, block 1204. During the period of time that data is being written to disk, the
12 tape drive continues to process the read tape command and to store data in its on-board buffer
13 memory 303.

14 Figure 13 illustrates the process of writing data to disk, block 204, in greater detail. This
15 process is similar to the process of Figure 10 which illustrated reading data from disk. Initially,
16 the tape application software calls standard operating system routines for accessing the tape drive.
17 The operating system routines attempt to call the disk service routine, block 1301. As has been
18 explained, especially with reference to Figure 8, 11 and 14, the application program replaced the
19 interrupt vectors of the ROM BIOS disk service routines with vectors to routines in the application
20 process. Therefore, the calls by the operating system routines to the disk service routines are
21 intercepted by the application process, block 1302. The application process then switches access
22 to the IDE bus to disk, block 1303 by setting the disk select bit 522.

23 To the extent not already specifically discussed, it should be noted that the disk select bit 522
24 provides for control of which device coupled with the IDE bus is to be accessed. When the host
25 writes the drive select register 503 to alter the state of the drive select bit, the task file registers of
26 both the disk and tape drive are effected. Likewise, when other registers are written by the host,

1 the task files of both drives are effected irregardless of which drive is selected by the drive select
2 bit 522. In the system of the preferred embodiment, when issuing a command, the host computer
3 first determines that the IDE bus is available by determining the state of the BUSY bit, 521. The
4 host then writes the disk select register, 522 followed by the other registers needed for the
5 operation and finally writes the command register 501 (as stated previously, the command register
6 is a dual purpose register and is used as the status register while the drive is executing a
7 command). The drives are each programmed such that only the drive selected by the drive select
8 bit 522 will respond to the command. As soon as the command is written, the BUSY bit is set and
9 the operation proceeds as has been described.

10 Again referring to Figure 13, the tape drive responds to being deselected by disabling DMA
11 transfers, block 1304, thus preventing inadvertent writing of data into its buffer memory during
12 transfers on the IDE bus directed to the disk.

13 The application software then calls the ROM BIOS INT 13 disk service routine, block 1305.
14 As a reminder, the application process has previously saved the address of this routine and, thus,
15 has the address available to call directly without having to access the interrupt vector 1403. The
16 disk service routine handles writing of data to the disk drive over the IDE interface. During the
17 time that the write data command is being processed, the disk drive sets the BUSY bit. During the
18 period of time when the BUSY bit is set, the disk drive performs DMA transfers from main
19 memory 106.

20 Upon completion of writing of data, the disk service routine returns control to the
21 application program, block 1306. The application program then writes the disk select bit 522 to
22 select the tape drive, block 1307, and the tape drive again enables DMA writes from the tape's
23 buffer memory to the main memory 104.

24 Thus, it can be seen that the present invention allows for effective simultaneous access to
25 two independently controlled devices both coupled with a host computer through a single interface.
26 This simultaneous access provides for improved performance of the devices, especially as

described in connection with the system of the preferred embodiment, during tape backup and restore processes.

TAPE DRIVE INTERFACE WITH STANDARD DISK CONTROLLER CIRCUITS

As one aspect of the present invention, it is taught to utilize industry standard disk drive controller circuits for control and interfacing of a tape drive. For example, as has been previously discussed, in the preferred embodiment a Cirrus Logic CL-SH-260 disk controller circuit is utilized as controller circuit 302. Responsive to the host interface 402 portion of the controller circuit 302 receiving a command from the host computer, the formatter portion of the circuit writes instructions to the write^{able} control store 409. An exemplary set of instructions is given with reference to Figure 6. The instructions may include such information as a command 601, a segment address 602 and count 603. Initially, a command may be given such as command 0001 to begin tape movement, followed by a command such as a synchronize command 0002, a write address mark command (WAM), and a command to begin writing data from the buffer memory 0004.

It is noted that in the data archival system of the present invention it is highly desirable to provide for compatibility with existing tape formats. Unfortunately, such existing tape formats are not compatible with standard disk drive formats, and especially with the write formats produced by standard controller circuits such as the Cirrus Logic CL-SH-260.

One area of incompatibility is in the the area of writing address marks. In writing address marks to standard disk drive formats a single address mark is typically written. The standard controller circuits begin CRC calculations when the write address mark command is issued. Standard tape drive formats require writing of three consecutive address marks to tape. Unfortunately, in order to provide for accurate calculation of the CRC, it is not desirable have the controller circuit 302 issue three separate write address mark instructions. Therefore, what is desired is to provide circuitry which will effectively provide for separation of the write address mark and "start CRC" instructions in a standard disk controller circuit such as the SH-260.

1 The present invention implements such circuitry by providing in the NRZ to MFM encoder
2 circuit 311 circuitry to effectively write three address marks each time an address mark is received
3 from the controller circuit 311. This circuitry may be referred to as an address mark generator. In
4 the preferred embodiment, encoder 311 is implemented as in a programmed logic array. In a
5 similar fashion, when reading information from tape, the controller circuit is programmed to start
6 CRC calculations upon receipt of each address mark. However, when reading standard tape
7 formats, as has been discussed, three consecutive address marks are read from tape and it is
8 required to begin calculation of the CRC with the first address mark and not to recalculate the CRC
9 for each of the address marks. Therefore, the MFM to NRZ decoder 312 of the present invention
10 provides address mark detection circuitry for detecting address marks and removing from the
11 information transmitted to the controller two of three address marks in a sequence of three
12 consecutive address marks. This is better illustrated with reference to Figure 7(a) and Figure 7(b).

13 Figure 7(a) illustrates the encoder 311 which receives NRZ (non-return to zero)
14 information from the controller circuit 302 and produces MRM (modified FM) output. The
15 encoder includes circuitry 701 (coded in a PLA circuit) for detecting instructions to turn on the
16 address mark on the NRZ input. In the prior art, as illustrated by signal 711, each turn address
17 mark on instruction will result in one address mark being generated on the MFM output to the
18 drive. The present invention provides for generation of three address marks responsive to each
19 turn address mark on instruction as illustrated by signal 712.

20 In a similar fashion, as illustrated by Figure 7(b), the present invention provides address
21 mark detection circuitry which detects sequences of three address marks being read from the drive
22 and being supplied on the MFM input to the decoder 312, such as the three address marks
23 illustrated by signal 732. Responsive to detecting three consecutive address marks, decoder 312
24 provides a single address mark output on the NRZ output to controller circuit 302.

1 In this way, the present invention provides for compatibility with standard disk drive
2 controller circuits allowing interface with the IDE bus while providing for compatibility with the
3 format of existing tape backup systems.

4

Thus, what has been described is an improved apparatus and method for providing for data
archival in a computer system. The described method is especially useful in computer systems
utilizing the Intelligent Device Electronics (IDE) interface, such as may be utilized by IBM PC-ATs
or compatibles.